A SIMPLIFICATION OF READING FLUID PROPERTIES USING MICROSOFT EXCEL

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ABSTRACT

This project deals with simplification reading fluid properties using Microsoft Excel. The objective of this project to develop an excel file to easily obtain fluid properties without manual reading from table. The types of fluid are saturated water, saturated refrigerant-134a, saturated ammonia, saturated propane and air at 1 atm pressure while the fluid properties are density, dynamic viscosity, kinematic viscosity and friction factor. The formula in Microsoft Excel, INDEX, MATCH, INDIRECT, IF, AND, ISBLANK, NA and DROPDDOWLIST are used to build a combine formula that can obtain fluid properties from property tables. The combined formula was constructed step by step starting the listed value, followed by listed and unlisted value for SI units only and then the listed and unlisted value for SI units and English units in the property tables. Finally, one more combined formula was constructed to obtain friction factor based on Colebrook equation by using bisection method to solve that equation. Validation results were conducted where compared the results from manual reading and excel file. The error from both results was observed where all the error results are below 5 % and can be accepted. The different results from manual reading and excel file only occur for result in value decimal places. It can be comprehend that, to obtain fluid properties from property tables can be using Microsoft Excel by constructed a excel file. The developed excel file for future work is highly recommended for adding more properties, more type of fluid and using Visual Basic for Applications for advance editing.

ABSTRAK

Projek ini berkaitan meringkaskan cara membaca sifat-sifat bendalir menggunakan Microsoft Excel. Objektif projek ini untuk membangunkan satu fail Microsoft Excel untuk memudahkan mendapat sifat-sifat bendalir tanpa membaca secara manual dari jadual. Jenis-jenis bendalir adalah air tepu, bahan pendingin-134a tepu, ammonia tepu, propana tepu dan udara pada tekanan 1 atm manakala sifat-sifat bendalir adalah ketumpatan, kelikatan dinamik, kelikatan kinematik dan faktor geseran. Formula dalam Microsoft Excel, INDEX, MATCH, INDIRECT, IF, AND, ISBLANK, NA dan DROPDDOWLIST digunakan untuk membina satu gabungan fomula untuk mendapatkan sifat-sifat bendalir dari jadual sifat-sifat bendalir. Gabungan fomula dibina peringkat demi peringkat dimulakan dengan nilai tersenarai, diikuti dengan nilai tersenarai dan tidak tersenarai untuk SI unit dan kemudiannya nilai tersenarai dan nilai tidak tersenarai untuk SI unit dan English unit dalam jadual sifat-sifat bendalir. Akhir sekali, satu lagi gabungan formula dibina untuk mendapatkan faktor geseran berdasarkan persamaan Colebrook dengan menggunakan kaedah pembahagian dua sama bagi menyelesaikan persamaan itu. Pengesahan keputusan telah dijalankan di mana membandingkan keputusan dari bacaan secara manual dan keputusan dari fail excel. Ralat dari kedua-dua keputusan telah diperhatikan di mana semua ralat adalah di bawah 5 % dan boleh diterima. Keputusan yang berbeza dari bacaan secara manual dan fail excel hanya berlaku pada nila tempat perpuluhan. Ia boleh difahami bahawa, untuk mendapatkan sifat-sifat bendalir dari jadual sifat-sifat bendalir boleh menggunakan Microsoft Excel dengan membina satu fail excel. Bagi penambahbaikkan projek ini pada masa hadapan, disyorkan menambah lebih banyak sifat-sifat bendalir, jenis-jenis bendalir dan menggunakan Visual Basic for Applications (VBA) untuk penambaikkan yang lebih baik.

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LIST OF SYMBOLS

f	Friction factor
f_D	Darcy friction factor
f_F	Fanning friction factor
ε	Roughness
D	Diameter
Re	Reynolds number
ρ	Density
μ	Dynamic viscosity
v	Kinematic viscosity
T	Temperature
V	Velocity

LIST OF ABBREVIATIONS

ASME	American Society of Mechanical Engineers
IST	International Skeleton Tables
ICPS	International Conference on the Properties of Steam
IFC	International Formulating Committee
IAPS	International Association for the Properties of Steam
IAPWS	International Association for the Properties of Water and Steam
SI	International System of Units
atm	Atmosphere
VBA	Visual Basic for Applications

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Fluid property tables are important to be referred by engineer to obtain the properties value to solve engineering problems. This project is simplification reading fluid properties without manually reading from table for some of the properties in the fluid property tables. Easier read the property table will shorten the time to solve problems.

Microsoft Excel is the software to simplification reading property tables. An excel file will construct where properties of fluid can be easily read simply by inserting the value of temperature in a certain cell and various fluid properties will automatically appear on any designated cells. The formulas in excel such as Match, Index, Indirect, If, And, Isblank, Na and Dropdownlist and other will use to obtain the properties.

1.2 PROBLEM STATEMENT

For manual reading property tables, it is quite difficult when interpolation is required if the value of the parameter is unlisted in the table and the time is very short. Interpolation calculation for unlisted value in property tables will cause the longer time taken to obtain that value in order to solve engineering task and problem. For Moody Chart, it is difficult to read manually because the Moody Chart is complicated that will increase the possibility to read the wrong value.

1.3 OBJECTIVE

The objective of this project is:

i. To develop an excel file to easily obtain fluid properties without manual reading from table

1.4 SCOPE OF THE PROJECT

The scopes of this project are limited to:

i. Fluid will be used are water, ammonia, refrigerant 134a, propane and air
ii. Fluid properties such as density, dynamic viscosity, kinematic viscosity and friction factor
iii. Based on table of fluid properties (McGraw Hill, 2006, Cengel Y.A and Cimbala J.M)
iv. Use Microsoft Excel 2007 software
v. Validation of results

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter discuss about literature review of the history of property tables, Moody Chart and Microsoft excel. Besides that, this chapter also discusses the existing software or calculator to obtain value from property tables and friction factor.

2.2 HISTORY OF PROPERTY TABLES

Property tables are important tool in the engineering field. Thermodynamics property tables and Fluid Mechanics property tables are the common use in mechanical engineering. The history of fluid property table is difficult to find compare to the history of steam table. The main used of property tables is for the industrial application and to solve the engineering problems especially in education.

In the history of steam table, James Watt in 1763 probably constructed the first steam table where he constructed a curve relating temperature and saturation pressure of water. There are four major steam tables were available in the middle of 1920s by Mark and Davis, by Goodenough, by Moiler and by Callendar where each table constructed density of steam as a function of temperature and pressure. Those four major steam tables had difference in published data and became a problem in the industry equipment performance. (Sifner, 2004)

Thus, to counter this problem, American Society of Mechanical Engineers (ASME) had a program of research that addresses the problem properties of steam in 1921. The program joined by Professor Callendar and followed by the German Research Authority. In the first World Power Conference, the country Czechoslovakia immediately invited after knowing Czechoslovakia had the research of properties of steam. (Sifner, 2004)

In 1929, the First International Steam-Table Conference was held in London, the second conference in Berlin in 1930 and in 1934, the third conference was held in Washington. In 1934, after many discussions and debates, engineers and scientist agreed the first International Skeleton Tables, IST'34 where this table only for limited range of temperature and pressure. This table become an important tool for engineer and famous as steam tables. (Sifner, 2004)

World war two was interrupted the international cooperation about 20 years. The steam tables needed to be extended due to increasing pressure and temperature of the power generating equipment. The fourth conference was renamed to the International Conference on the Properties of Steam (ICPS) was held in Philadelphia in 1954 while fifth conference in London in 1956 and sixth conference in New York in 1963. These conferences were discussed and developed of new standards for water and steam properties. (Sifner, 2004)

The seventh conference ICPS was held in Tokyo adopted two final versions namely The 1967 IFC Formulation for Industrial Use for simpler equations but sufficient accuracy and The 1968 IFC Formulation for Scientific and General Use for accurate description of properties. International Association for the Properties of Steam (IAPS) was established at the seventh conference and now known as International Association for the Properties of Water and Steam (IAPWS). (Tremaine et al., 2008)

The eighth conference was held in Giens, France in 1974 to construct new tables of viscosity and thermal conductivity. In that conference, it also discussed to prepare

the surface tension formulation. Ninth conference was held in Munich in 1979 to discuss new tables and new thermodynamic formulations. In 1984, the tenth conference was held in Moscow adopted a new thermodynamic standard for general and scientific use. (Sifner, 2004)

Eleventh conference was held in Prague, Czechoslovakia in 1989 while the twelfth conference was held in Orlando, USA in 1994. In 1995, the new Formulation for Industrial Use known as IAPWS-95 was adopted to replace previous version while in 1997 the new Formulation for Scientific and General Use was adopted known as IAPWS-IFC97. The thirteenth conference was held in Toronto, Canada in 1999, fourteenth conference was held in Kyoto in 2004 and fifteenth conference was held in Berlin in 2008. (Tremaine et al., 2008)

Properties of saturated water

Temp. T, °C	Saturation Pressure P_{sat}, kPa	Density ρ, kg/m³ Liquid	Density ρ, kg/m³ Vapor	Enthalpy of Vaporization h_{fg}, kJ/kg	Specific Heat c_p, J/kg · K Liquid	Specific Heat c_p, J/kg · K Vapor	Thermal Conductivity k, W/m · k Liquid	Thermal Conductivity k, W/m · k Vapor	Dynamic Viscosity μ, kg/m · s Liquid	Dynamic Viscosity μ, kg/m · s Vapor	Prandtl Number Pr Liquid	Prandtl Number Pr Vapor	Volume Expansion Coefficient β, 1/K Liquid
0.01	0.6113	999.8	0.0048	2501	4217	1854	0.561	0.0171	1.792×10^{-3}	0.922×10^{-5}	13.5	1.00	-0.068×10^{-3}
5	0.8721	999.9	0.0068	2490	4205	1857	0.571	0.0173	1.519×10^{-3}	0.934×10^{-5}	11.2	1.00	0.015×10^{-3}
10	1.2276	999.7	0.0094	2478	4194	1862	0.580	0.0176	1.307×10^{-3}	0.946×10^{-5}	9.45	1.00	0.733×10^{-3}
15	1.7051	999.1	0.0128	2466	4185	1863	0.589	0.0179	1.138×10^{-3}	0.959×10^{-5}	8.09	1.00	0.138×10^{-3}
20	2.339	998.0	0.0173	2454	4182	1867	0.598	0.0182	1.002×10^{-3}	0.973×10^{-5}	7.01	1.00	0.195×10^{-3}
25	3.169	997.0	0.0231	2442	4180	1870	0.607	0.0186	0.891×10^{-3}	0.987×10^{-5}	6.14	1.00	0.247×10^{-3}
30	4.246	996.0	0.0304	2431	4178	1875	0.615	0.0189	0.798×10^{-3}	1.001×10^{-5}	5.42	1.00	0.294×10^{-3}
35	5.628	994.0	0.0397	2419	4178	1880	0.623	0.0192	0.720×10^{-3}	1.016×10^{-5}	4.83	1.00	0.337×10^{-3}
40	7.384	992.1	0.0512	2407	4179	1885	0.631	0.0196	0.653×10^{-3}	1.031×10^{-5}	4.32	1.00	0.377×10^{-3}
45	9.593	990.1	0.0655	2395	4180	1892	0.637	0.0200	0.596×10^{-3}	1.046×10^{-5}	3.91	1.00	0.415×10^{-3}
50	12.35	988.1	0.0831	2383	4181	1900	0.644	0.0204	0.547×10^{-3}	1.062×10^{-5}	3.55	1.00	0.451×10^{-3}
55	15.76	985.2	0.1045	2371	4183	1908	0.649	0.0208	0.504×10^{-3}	1.077×10^{-5}	3.25	1.00	0.484×10^{-3}
60	19.94	983.3	0.1304	2359	4185	1916	0.654	0.0212	0.467×10^{-3}	1.093×10^{-5}	2.99	1.00	0.517×10^{-3}
65	25.03	980.4	0.1614	2346	4187	1926	0.659	0.0216	0.433×10^{-3}	1.110×10^{-5}	2.75	1.00	0.548×10^{-3}
70	31.19	977.5	0.1983	2334	4190	1936	0.663	0.0221	0.404×10^{-3}	1.126×10^{-5}	2.55	1.00	0.578×10^{-3}
75	38.58	974.7	0.2421	2321	4193	1948	0.667	0.0225	0.378×10^{-3}	1.142×10^{-5}	2.38	1.00	0.607×10^{-3}
80	47.39	971.8	0.2935	2309	4197	1962	0.670	0.0230	0.355×10^{-3}	1.159×10^{-5}	2.22	1.00	0.653×10^{-3}
85	57.83	968.1	0.3536	2296	4201	1977	0.673	0.0235	0.333×10^{-3}	1.176×10^{-5}	2.08	1.00	0.670×10^{-3}
90	70.14	965.3	0.4235	2283	4206	1993	0.675	0.0240	0.315×10^{-3}	1.193×10^{-5}	1.96	1.00	0.702×10^{-3}
95	84.55	961.5	0.5045	2270	4212	2010	0.677	0.0246	0.297×10^{-3}	1.210×10^{-5}	1.85	1.00	0.716×10^{-3}
100	101.33	957.9	0.5978	2257	4217	2029	0.679	0.0251	0.282×10^{-3}	1.227×10^{-5}	1.75	1.00	0.750×10^{-3}
110	143.27	950.6	0.8263	2230	4229	2071	0.682	0.0262	0.255×10^{-3}	1.261×10^{-5}	1.58	1.00	0.798×10^{-3}
120	198.53	943.4	1.121	2203	4244	2120	0.683	0.0275	0.232×10^{-3}	1.296×10^{-5}	1.44	1.00	0.858×10^{-3}
130	270.1	934.6	1.496	2174	4263	2177	0.684	0.0288	0.213×10^{-3}	1.330×10^{-5}	1.33	1.01	0.913×10^{-3}
140	361.3	921.7	1.965	2145	4286	2244	0.683	0.0301	0.197×10^{-3}	1.365×10^{-5}	1.24	1.02	0.970×10^{-3}
150	475.8	916.6	2.546	2114	4311	2314	0.682	0.0316	0.183×10^{-3}	1.399×10^{-5}	1.16	1.02	1.025×10^{-3}
160	617.8	907.4	3.256	2083	4340	2420	0.680	0.0331	0.170×10^{-3}	1.434×10^{-5}	1.09	1.05	1.145×10^{-3}
170	791.7	897.7	4.119	2050	4370	2490	0.677	0.0347	0.160×10^{-3}	1.468×10^{-5}	1.03	1.05	1.178×10^{-3}
180	1,002.1	887.3	5.153	2015	4410	2590	0.673	0.0364	0.150×10^{-3}	1.502×10^{-5}	0.983	1.07	1.210×10^{-3}
190	1,254.4	876.4	6.388	1979	4460	2710	0.669	0.0382	0.142×10^{-3}	1.537×10^{-5}	0.947	1.09	1.280×10^{-3}
200	1,553.8	864.3	7.852	1941	4500	2840	0.663	0.0401	0.134×10^{-3}	1.571×10^{-5}	0.910	1.11	1.350×10^{-3}
220	2,318	840.3	11.60	1859	4610	3110	0.650	0.0442	0.122×10^{-3}	1.641×10^{-5}	0.865	1.15	1.520×10^{-3}
240	3,344	813.7	16.73	1767	4760	3520	0.632	0.0487	0.111×10^{-3}	1.712×10^{-5}	0.836	1.24	1.720×10^{-3}
260	4,688	783.7	23.69	1663	4970	4070	0.609	0.0540	0.102×10^{-3}	1.788×10^{-5}	0.832	1.35	2.000×10^{-3}
280	6,412	750.8	33.15	1544	5280	4835	0.581	0.0605	0.094×10^{-3}	1.870×10^{-5}	0.854	1.49	2.380×10^{-3}
300	8,581	713.8	46.15	1405	5750	5980	0.548	0.0695	0.086×10^{-3}	1.965×10^{-5}	0.902	1.69	2.950×10^{-3}
320	11,274	667.1	64.57	1239	6540	7900	0.509	0.0836	0.078×10^{-3}	2.084×10^{-5}	1.00	1.97	
340	14,586	610.5	92.62	1028	8240	11,870	0.469	0.110	0.070×10^{-3}	2.255×10^{-5}	1.23	2.43	
360	18,651	528.3	144.0	720	14,690	25,800	0.427	0.178	0.060×10^{-3}	2.571×10^{-5}	2.06	3.73	
374.14	22,090	317.0	317.0	0	—	—	—	—	0.043×10^{-3}	4.313×10^{-5}			

Figure 2.1: Sample of fluid property tables

Source: Cengel and Cimbala (2006)

Figure 2.1 show the sample of fluid property tables that are important tool as the reference in industry for engineer to solve engineering problem. International Association for the Properties of Water and Steam (IAPWS) is the association that concern with the properties of water and steam.

2.3 HISTORY OF MOODY CHART

Moody Chart or Moody Diagram was used by engineering worker and engineering student since 1940s. Lewis F. Moody was the responsible person which had developed Moody Chart in 1944 and this Moody Chart was published by American Society of Mechanical Engineers (ASME). Moody Chart is semi-empirical that related to the Darcy friction factor, relative roughness and Reynolds number. (McGovern, 2003)

Cyril F. Colebrook in 1939 was developed Colebrook equation where that equation comes from combined available data for transition and turbulent flow in smooth. The Colebrook equation is:

$$\frac{1}{\sqrt{f}} = -2\log\left(\frac{\varepsilon/D}{3.7} + \frac{2.51}{Re\sqrt{f}}\right) \tag{2.1}$$

The American engineer, Hunter Rouse in 1942 had verified Colebrook equation and developed a graphical plot of friction factor, f as a function of Reynolds number, Re. From Rouse diagram, Lewis F. Moody redrew that diagram and produced the Moody Chart. (Cengel and Cimbala, 2006)

There are two common of friction factor which the first Darcy friction factor, f_D and the second Fanning friction factor f_F. Fanning friction factor equal to one quarter of the Darcy friction factor shows in equation below: (McGovern, 2003)

$$f_F = \frac{f_D}{4} \tag{2.2}$$

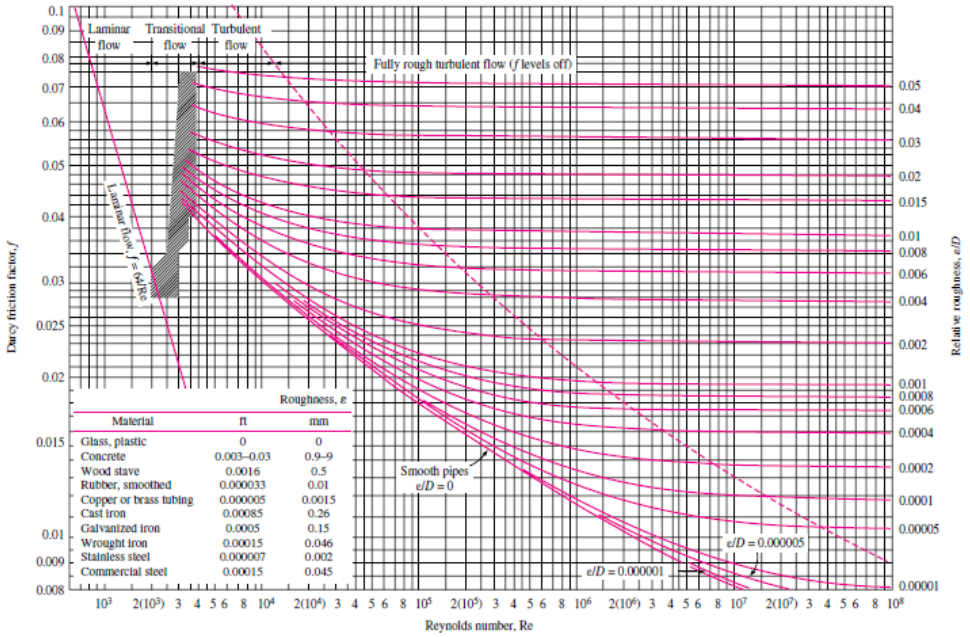

FIGURE A–20

The Moody chart for the friction factor for fully developed flow in circular pipes for use in the head loss relation $\Delta P_L = f\frac{L}{D}\frac{\rho V^2}{2}$. Friction factors in the turbulent flow are evaluated from the Colebrook equation $\frac{1}{\sqrt{f}} = -2\log_{10}\left(\frac{\varepsilon/D}{3.7} + \frac{2.51}{\mathrm{Re}\sqrt{f}}\right)$.

Figure 2.2: Moody Chart

Source: Cengel and Cimbala (2006)

Figure 2.2 show the Moody Chart that was included in many mechanical engineering books like Fluid Mechanics and Heat Transfer. From Moody Chart, known the value of Reynolds number and relative roughness, the friction value can be obtained.

2.4 HISTORY OF MICROSOFT EXCEL

Microsoft Excel is one of the spreadsheet program that allow user to organize, format, calculate data with formula, graphing tools, pivot tables and macro programming language called visual basic for application. Once an excel file was constructed, the contents can modified by adding and deleting where the result recalculated automatically. In 1979, Dan Bricklin constructed the first spreadsheet program on a personal computer was called visible interactive calculator (VisiCalc). (Martin, 2010)

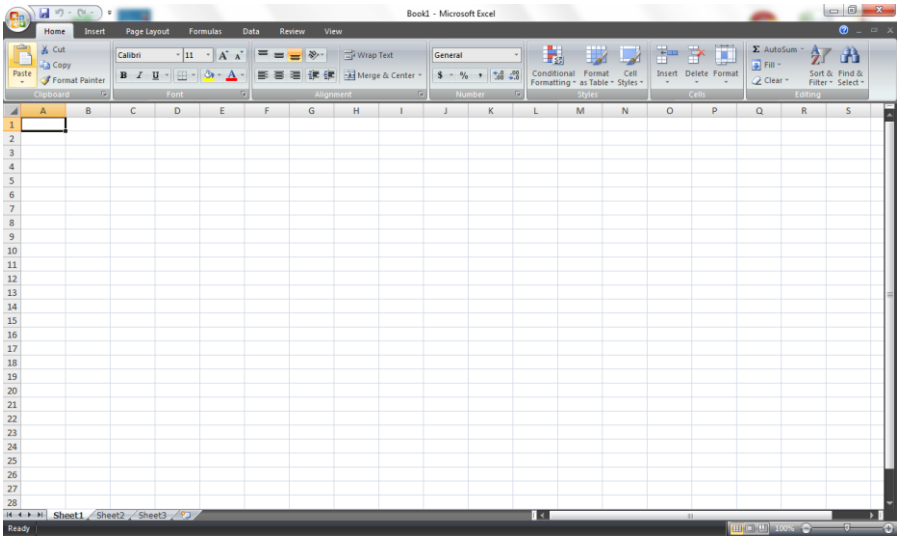

Figure 2.3: View of Microsoft Excel 2007

Figure 2.3 show view of Microsoft Excel 2007 that developed by Microsoft. In 1975, Paul Allen and Bill Gates formed a company namely Microsoft. In 1982, Microsoft released spreadsheet program known as Multiplan. Then, Microsoft was released first version of excel in 1985 but for Macintosh operating system only. In 1987, second version of excel was released for the first Windows operating system. (Pearson, 2011)

Excel third version was released in 1990 with new features included worksheets. In 1992, Excel fourth version was released with included lots of usability features and become the first popular version. Excel fifth version was released in 1993 with new features included multiple worksheets and support visual basic for applications. (Power, 2004)

New version of Excel was rebranded as Excel 95 in 1995 along with other Microsoft Office 95 programs. Excel 95 was the seventh version where there was no sixth version of excel. This Excel 95 was the 32 bit version. Then, Excel 97 was released in 1997 with new visual basic for applications and new features included user forms and data validation. In 1999, new excel was released known as Excel 2000. Excel 97 was the eighth version and Excel 2000 was the ninth version. (Pearson, 2011)

Excel 2002 was released in 2001 while Excel 2003 was released in 2003 where Excel 2002 was the tenth version and Excel 2003 was the eleventh version. Excel 2007 was released in 2007 with a lot of improvements. Excel 2010 was the latest Excel version builds on Excel 2007 with not any major changes. Excel 2007 was the twelfth version and Excel 2010 was the fourteenth version where there was no thirteenth version of excel. Table 2.1 shows the various versions of Microsoft Excel. (Pearson, 2011)

Table 2.1: The various versions of Microsoft Excel

Version	Released	Comments
1	1985	For Macintosh operating system
2	1987	First for Windows operating system
3	1990	Features included worksheets, toolbar, outlining and drawing capabilities
4	1992	Lots of usability features and first popular version
5	1993	Included multiple worksheets and visual basic for applications
6	-	There was no sixth version
7	1995	32-bit first version, rebranded as Excel 95
8	1997	New visual basic for applications, user forms and data validation interface namely as Excel 97
9	1999	Known as Excel 2000
10	2001	A lot of new features namely as Excel 2002
11	2003	Namely as Excel 2003
12	2007	A lot of improvements namely as Excel 2007
13	-	There was no thirteenth version
14	2010	Builds on Excel 2007 with not any major changes namely as Excel 2010

Source: Pearson (2011)

2.5 EXISTING SOFTWARE OR CALCULATOR FOR FLUID PROPERTY TABLES AND MOODY CHART

There are a lot of software or calculator to obtain fluid property tables and Moody Chart in the market. However, majority of the software is commercial that require user to buy the software. Some of the software must be paid before download or utilize for trial version and use it for certain period. For the calculator, internet connection is required to use it because there is no requirement to download and install it into the computer. This software or calculator has their own advantages and disadvantages. There is the several existing software or calculator for fluid in property tables and Moody Chart:

i. Fluid Properties Calculator

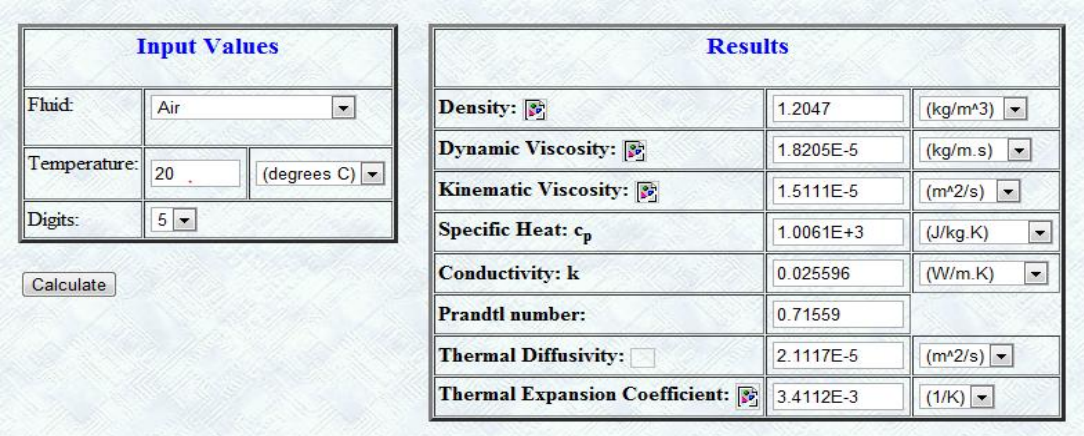

Figure 2.4: View of fluid properties calculator

Source: Yovanovich et al. (1998)

Figure 2.4 shows the fluid properties calculator was developed by Microelectronics Heat Transfer Laboratory. For properties of air, argon, nitrogen and hidrogen, it calculated based on correlations developed by F. McQuillan while for properties of carbon dioxide, water and the ethylene glycols it calculated based on the